Seguin (E. C.)

AN OUTLINE

OF THE

PHYSIOLOGY OF THE NERVOUS SYSTEM.

BY

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PHYSIOLOGY OF THE NERVOUS SYSTEM.*

By E. C. SEGUIN, M.D.

Gentlemen:—In thinking of a subject to present to you in an introductory lecture, it occurred to me that a good one would be a sketch, very much condensed, of the anatomy and physiology of the central nervous system, to serve as a basis upon which we can, during the winter, build up a knowledge of diseases of the brain. I shall be very brief upon the individual heads of the lecture, wasting no time upon matters which are not capable of bearing a logical relation to pathology.

Before entering upon the subject proper, I wish to say a few words, intended to give you a clearer idea of the relation of medical to general knowledge. I mean to warn you against the error which it must be said some of the books in your hands tend to strengthen and perpetuate, viz., the separation of physiology from pathology, and the confounding of the latter with pathological anatomy. If we look at the matter from an extra-medical or philosophical point of view, we are led to classify our knowledge of the animal body into two categories: statical and dynamical knowledge. In other words, we study the animal organism and its parts in a state of rest, and in a state of activity; we observe the form and constitution of parts, and determine their properties and functions.

The study of the human body and its parts in a state of rest is called anatomy, in the broad sense of the word, making it to include chemical and microscopical analysis. Anatomy is spoken of as normal (with many subdivisions) when it describes the healthy parts and tissues; as pathological or morbid when it

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treats of the changes produced in tissues and parts by disease.

Our dynamical knowledge, embracing the study of the properties and functions of the parts we have anatomically analyzed, is called physiology; and this must, like anatomy, be separated into two great subdivisions—physiology, strictly speaking, and pathological (or morbid) physiology, or pathology. The activities we observe in abnormal (pathological) states are not different in kind from those which pervade the organism in health; nor are the laws of derivation and utilization of these activities different from the laws which operate in the normal body. By close analysis we find that in diseased states, as in health, physical and chemical laws govern the frame, and that essentially the results of their operation are the same. It can, I believe, be demonstrated with all but mathematical exactness, that the great law of conservation and correlation of force is supreme in the disordered and in the perfect animal organism. There is and can be no entity of disease, no demon. Even therapeutics can be brought into accord with this conception of medical knowledge; for our medicines and remedial agents are only means by which we aim to act upon the human body in such a way as to modify the shape or constitution of its parts, and to alter the mode of activity of its tissues and organs. And although the *modus operandi* of most medicines is obscure as yet, I think it not rash to say that medicinal agents do not act in any supernatural or occult way, but by the laws of physics and chemistry.

The study of the physiologist, and of the pathologist as well, begins with the nutrition of simple tissues, single cells, or even masses of protoplasm; and upon such a study, as a basis, there is built up the more complicated and elaborated knowledge of the activities of the human body which the practical physician needs so much at the bedside.

A consideration of what I have said will, I trust, lead you to admit two propositions: first, that we physicians are in reality naturalists, studying what we call disease by natural and scientific methods; second, that the most excellent physician must be the man who (contrary to a vulgar prejudice), together with a practical turn of mind and a sympathetic na-

ture, has the greatest amount of scientific knowledge at his command.

I have thus apparently gone out of my way in order to help you in viewing this lecture as a logical whole, an imperfect attempt to give you a guiding plan in your studies of diseases of the nervous system.

The subject of the lecture is naturally divisible into three parts.

1st. A study of the elementary parts of the central nervous system—their anatomical attributes and physiological properties.

2d. A study of the organs and apparatuses in the central nervous system, and their functions.

3d. A summary of the chief modifications of the properties and functions which constitute the symptomatology of disease.

1. The part comprising the nervous centres may be classified as follows:

A. Bindweb (neuroglia).

B. Bloodvessels and lymphatic spaces.

C. Nerve fibres $\begin{cases} \text{myelinic.} \\ \text{amyelinic.} \end{cases}$

D. Nerve cells (ganglion cells).

A. The bindweb, gentlemen, is the framework in which lie the strictly nervous elements of the nervous system; it incloses and supports nerve fibres, nerve cells, and bloodvessels. Its histological composition is that of a fibro-connective tissue, according to the latest observations. In it we meet with bundles of connective-tissue fibres, with exceedingly delicate fibrillæ of fibrous tissue, and with more or less altered cells lying often at the point of meeting of the fibrillæ. The fibrous fibrillæ are more immediately in relation with the nerve fibres and cells, while the connective tissue, constituting the septa and the cortical layer of the spinal cord, are united at the periphery with the pia mater, or innermost membrane of the three surrounding the brain and cord. The bindwebs of the brain and spinal cord are similar in kind, but the cerebral fibro-connective tissue is much the more delicate. The statements that there is a "granular matter" in the neuroglia, or that it is a sponge-like tissue, I believe from personal observations to be based upon inexact observations. At any rate, it suffices for our purpose to know the bindweb as a form of connective

tissue, containing nuclei which may be the starting-point of proliferation changes tending to truly pathological, or to reparative changes.

B. The bloodvessels of the nervous centres are very abundant, and are in many respects peculiar. The capillaries are by far more numerous in the gray matter of both encephalon and spinal cord than in the white substance. The larger vessels all reach the nervous organs through the pia mater. The rarity of anastomoses between the arteries in the cord and brain is a most striking feature, and is closely related with pathological processes. The non-capillary vessels are remarkable for the relatively extreme development of their muscular coat. The greatest peculiarity presented by these vessels, however, consists in their having an outer sheath, constituting a canal separated from the vessel by a small amount of fluid. All the vessels of the cerebro-spinal mass are thus inclosed. These so-called perivascular canals are made up of very delicate connective (structureless?) tissue, and contain a fluid very analogous to lymph. The perivascular canals are an extension into the parenchyma of a vast system of lymphatic spaces which surround the nervous centres, the so-called sub-arachnoid space in the meshes of the pia mater around the brain and spinal cord. This arrangement has been known for several years; and we now know, by the recent investigations of Ranvier and Axel Key, that the same sub-arachnoid or lymphatic space extends outward with every cerebral and spinal nerve to its termination. You should imagine the nervous system—brain, spinal cord, and their nerves—as floating in lymphoid fluid, contained in a delicate connective-tissue envelope. Even in the eyeball and internal ear these lymph spaces have been demonstrated. We are only beginning to appreciate the bearing of these important anatomical discoveries to pathological processes. It has been stated that nerve cells, in the cerebral convolutions especially, are surrounded by a similar lymphatic space—an extension of the one described—but this is, I am convinced, an error of interpretation, the space seen having been produced by the shrinkage of the cells under certain modes of preparation.

C. Nerve fibres. Several classifications of nerve fibres are in use, but the simple one of two classes—

myelinic and amyelinic—will suffice for us physicians. By the term myelinic nerve fibre is meant a complete nerve fibre, one consisting of three parts—a central body or axis cylinder, a surrounding mass of fatty substance, the myeline, and a structureless enveloping sheath (the membrane of Schwann). In some parts of the nervous system the last element is absent. The amyelinic fibre is simply a naked axis cylinder. You see from these definitions, that the essential part of the three is the axis cylinder, the other two, which may be called insulating, are superadded. The amyelinic fibres are met with in the gray substance mostly, but are also abundant in the sympathetic nerves. We find myelinic nerve fibres, without the membrane of Schwann, and varying infinitely in size, in the white columns of the spinal cord, and in the white substance of the encephalic mass, constituting the bulk of these parts. There are also such fibres, though minute ones, in the gray substance of the cord and brain. The peripheral parts of the nervous system, all the cerebral and spinal nerves, and a part of the sympathetic, are made up of the second variety of myelinic fibres—those which have the three parts.

A peculiarity of nerve fibres is that they extend independently of each other, *i.e.*, not anastomosing, from their origin to their distribution, from nerve-cells in the central nervous mass to peripheral organs; and this isolation of nerves, together with their insulation, explains a physiological attribute to which I shall call your attention. I should add that forty years ago it was believed that nerve fibres extended from the brain to the outer parts of the body, and that the spinal cord was chiefly a bundle of nerves. Progress has strongly tended to take this supremacy away from the brain, to show us the importance of the spinal cord as a centre; and we now believe that nerve fibres once in the spinal cord run only a comparatively short distance before uniting with nerve cells.

D. nerve cells are the noblest elements of the nervous system; those which possess the power of generating force in the modern acceptance of the phrase, *i.e.*, the property of evolving nerve force out of chemical activity. They are found in greatest number in the brain, spinal cord, and sympathetic nervous system—aggregations of them constituting gray

matter or ganglia. Nerve cells, wherever found, consist of organized matter, call it protoplasm if you will, not inclosed in any cell membrane, sending out prolongations or processes of various shapes and lengths, containing a globular body called the nucleus, which itself incloses a smaller body termed the nucleus. These nerve cells vary in size, in shape, and in the number of their processes. The largest ganglion cells are met with in the anterior gray horns of the spinal cord in its lumbar and cervical enlargements. In the ox, cells taken from these localities are almost visible to the naked eye. In the floor of the fourth ventricle (medulla oblongata) and in certain parts of the base of the brain large cells are also found. The smallest cells occur in the gray matter of the cerebral convolutions, and in parts of the medulla oblongata. As regards shape, four subdivisions may be recognized: polyhedral, pyramidal, oval, and round. The first are met with in the same location as the largest cells; the pyramidal are nearly restricted to the cerebral convolutions; oval cells are found in the median and posterior parts of the gray matter of the cord, and in the medulla; round cells in the sympathetic and in the ganglia of the posterior roots of the spinal nerves. With respect to the disposition of their processes, cells are distinguished as multipolar, bipolar, and apolar. I do not believe in the existence of apolar nerve cells. Under the name of multipolar cells we include a majority of ganglion cells; those of the cerebral cortex exhibiting from three to six processes, the large cells of the medulla and spinal cord showing a great many—eight, twelve, or more. Bipolar cells are rarely seen in preparations from the human nervous centres. The separation of cell processes into two classes was an important progress. A multipolar cell sends out one stout, thick process, which extends a long distance, not subdividing, ultimately forming, with the addition of myeline, a nerve fibre. The same cell also throws off an indefinite number of processes of unequal size, which rapidly subdivide, growing smaller and smaller. The former is the "cylinder axis process;" the latter are the "protoplasma processes," and their destination is unknown. It has been claimed that the number of processes and the size of cells afford an indication of their special functions, but that is not be-

lieved to-day. I should add that the communications between cells which you will find figured in books do not exist; and that the communication of nerve fibres with nerve cells has been demonstrated, though a very few times.

These elementary structures, while alive and forming a part of the animal body, possess certain physiological properties, some common to all, others the special attributes of individual parts. The most common of these physiological properties is that of being osmotic, *i.e.*, of allowing fluids to pass through them. This property is possessed in a very high degree by capillary vessels, by arterioles, venules, and the perivascular sheaths—the escape of material from them to the tissues, and *vice versâ*, being very rapid and free. The bindweb, also, has the osmotic property in a high degree, and thus serves as an aid to nutrition as well as a mechanical support. Nerve fibres and nerve cells are undoubtedly osmotic, but to a much less degree. Wherever it exists, this important process is under the same laws; it is only possible when liquids of different density are on either side of the membrane; its rapidity is increased by motion, pressure, heat, and chemical action, all of these being found in the living nervous centres.

Chemical changes of a very complicated sort are going on constantly in the cells and nerve fibres of the central nervous system, constituting the essence of nutrition. In a state of health the acquisition of new material by the tissues is so balanced with the separation of effete matter, that, in spite of great internal activity, the parts are maintained in an uniform (not mathematically equal) condition. We should never forget that this chemical action in myriads of parts cannot take place without producing other correlative effects, such as nerve force, heat, and electric currents.

Nerve fibres possess certain special physiological properties. In the first place, they conduct the impressions they receive, in both directions, from the central organs to the periphery and *vice versâ*. This conduction is not by any means instantaneous or even very rapid, as it takes place in isolated nerve fibres at the rate of less than sixty yards per second, whereas the speed of electricity is 464,000,000 yards; that of

light, 300,000,000; that of sound, 332; that of a cannon-ball, 552. In the living body the rate of transmission is from forty to forty-five yards. This conduction is done, furthermore, in a perfectly isolated way by individual nerve fibres: there is no interference between fibres on their way to and from the central organs. Nerve fibres are excitable, that is, respond to stimuli—mechanical, chemical, and electrical—by motor manifestations or by sensations when the motor or sensory filaments are experimented upon. This excitability is quite independent of the nervous centres, and is inherent to the nerve, as is shown by the fact that a nerve continues to react to stimuli for three days after its separation from continuity with the nervous centre.

Nerve cells have properties whose existence we learn in part through reasoning by exclusion, after having ascertained the properties of nerve fibres, and in part by direct experimentation. In the first place, certain nerve cells have the power of furnishing force (motor impulse) to nerves and muscles; this is called motricity by some authors. Another property of nerve cells is sensitivity, that is, the property of transforming impressions received from without by and through the sensory nerves into a sensation. That nerve cells possess a power over the nutrition of parts non-nervous, we now incline to believe; but we hardly yet dare name and define this property. But nerve cells have, I believe, yet one physiological property, viz., that of retaining impressions made upon them; a property for which I now propose the term retentivity. I have for some time believed that nerve cells (and other cells to a degree) do in all parts what it is acknowledged they do in the cerebral convolutions—they possess memory, or the property of registering or retaining impressions. That this is probable is shown by the fatality of numerous actions occurring a second time and oftener. The occurrence of a sensation will give rise to a flow of ideas associated with the sensation, and this under normal conditions will be repeated whenever the sensation is renewed. An action of the class, called reflex or sensori-motor, is, after its first performance, fatally repeated whenever the same initial sensory irritation occurs. A bolus of mixed foods passing down the alimentary canal pro-

vokes in a necessary or fatal way the action of various muscular, vascular, and glandular organs. The well-known experiment of placing a drop of acid near a frog's anus, after decapitation, illustrates my view of the possession of memory by the nerve-cells of the spinal cord; for in this experiment the hinder legs of the animal are drawn up and moved in an apparently intelligent manner, in such a way as to remove the irritating acid. Three years ago, in spring lectures given here, I explained this phenomenon by saying, that the frog having during its life often performed this act for the same purpose, its occurrence after cerebral death takes place by necessity, because the same sensation is transmitted to the spinal cord. Additional proof of the correctness of this theory is to be obtained from a study of the mode of acquisition and retention of complex co-ordinate movements, such as walking, dancing, piano-playing, etc. Motricity, sensitivity, and retentivity are therefore the chief special physiological properties of nerve cells.

Let us now, gentlemen, resume our statical, or, if you please, anatomical study. The various nervous elements which I have sketched for you are combined in the living body in such a way as to constitute organs and apparatuses. The term organ I would apply to such parts as are the seat of performance of relatively limited and less important functions, while by apparatus I understand a combination of organs serving for the evolution of important and comprehensive functions. The spinal cord, medulla oblongata, pons Varolii, cerebellum, and cerebrum may be named as the central nervous organs, made up as follows: The cerebrum consists of a superficial or cortical layer of gray matter, *i.e.*, of tissue made up of nerve cells, and both kinds of nerve fibres (myelinic and amyelinic), arranged in a somewhat complicated way. This gray matter rests upon the white substance composed of myelinic fibres, which extend downward and inward to certain basal gray bodies or ganglia, the optic thalamus, and the corpus striatum; or the white substance may be described as radiating from these bodies toward the peripheral gray matter, which latter is arranged in folds called convolutions or gyri. The cerebellum has an analogous structure, with variations—the corpus dentatum as central gray

body, and white substance radiating thence to the peripheral convolutions. The pons Varolii is made up of white substance on its outer and anterior parts, with masses of gray matter within. In the medulla oblongata we find an analogous structure, white matter at the periphery, and gray matter in the centre and posteriorly. The floor of the fourth ventricle contains a series of most important ganglia (masses of gray matter). The spinal cord has the same structure throughout its length—a structure best described upon a transverse section. Such a section is seen to consist of symmetrical halves, each containing a central gray mass and peripheral white matter. The gray matter is divided into anterior and posterior masses, the so-called horns, of which the anterior is the larger. The posterior horn reaches out to the margin of the organ, but everywhere else there is white substance outside of the gray horns. The shape of the gray horns and the relative proportion of white and gray substances vary in different parts of the cord, but that does not immediately concern us. From the spinal cord, symmetrical on either side, are the roots of nerves; the posterior roots being attached to the cord just inside of the posterior horn, the anterior roots issuing from the anterior mass of white matter. Upon the posterior root, just before it conjoins with the anterior root, we see a small swelling which is a mass of gray matter—a ganglion. The white peripheral matter is usually subdivided in each half of the spinal cord into two parts—the antero-lateral columns, and the posterior columns—the dividing line between them being the posterior gray horn, where it strikes the periphery of the organ. A microscopic central canal runs the entire length of the spinal cord, continuous with the large openings, called the ventricles in the encephalic masses. Just at the junction of the spinal cord and medulla oblongata, in front, is seen a limited spot where bundles of white substance cross the median line, being myelinic fibres extending from the anterior column or pyramid of one side of the medulla to the antero-lateral column of the other side of the cord, constituting the so-called decussation of the pyramids.

The encephalic nerves all terminate in parts below the hemispheres and cerebellum. If I add that histologically and morphologically every part beneath the

cerebrum, cerebellum, and opto-striate bodies belong to the spinal cord, it will be truthful, and of great help in our physiological and pathological studies. Ever since I began lecturing here, four years ago, I have taught this natural division of the nervous centres into the spinal axis, cerebellum, and cerebrum. Accepting this classification of the centres, we can also say that with the exception of the olfactory, all nerves are spinal, which philosophically is perfectly true.

I will now call your attention to certain great functions of the central nervous system—functions which involve the entering into activity of large tracts of nervous tissue extending over one or more of the organs just enumerated. I allude to the conduction of sensations, the transmission of motor impulses, the so-called reflex action, and co-ordination of movement.

In the first place, about the conduction of sensations. How are sensations formed in the spinal gray matter transmitted upward so as to be put within reach of the higher sensibility we call consciousness? To this question only a very partial answer is possible, mainly with reference to the direction of conduction. It is quite surely ascertained that a sensation originating in an irritation of the right lower extremity is perceived by the left cerebral hemisphere, and the left half of the pons Varolii. In other words, the sensory nerves, or better, the sensory paths, all cross the median line somewhere in the spinal axis. We owe chiefly to the experimental inquiries and pathological observations of Brown-Séquard the demonstration of two most important facts in this connection: (1) That these paths cross the median line (decussate) almost immediately after entering the cord, and then extend upward in the opposite half of the organ to the seat of consciousness; (2) and that it is the central gray matter, not the posterior columns, which contains these paths. This almost horizontal decussation has been shown to take place at the origin of every spinal nerve; in other words, sensory decussation is complete throughout the spinal axis. There seem to be good experimental and pathological reasons for believing that the perception of sensation (their appreciation by consciousness) takes place in the pons Varolii; though cerebral action must intervene in the most complete

perception, that including recognition of cause of irritation. I cannot leave the subject of transmission of sensations without adding a few words about a great law, a proper understanding of which is of great help to us in diagnosis, I mean the law of reference of sensations. By reference of sensations we mean the fact that when a sensory nerve is irritated at any point, at its termination (normal way), its middle, or at its origin in the spinal axis, the resulting sensation is felt in the parts to which the nerve is distributed. To illustrate: If I touch the table with my two outer fingers, I correctly refer the sensation to the vicinity of the pulp of these fingers; if I strike the ulnar nerve behind the elbow, the greatest sensation is felt in the tips of the little and ring fingers, which this nerve supplies, and if I could irritate the spinal origin of the ulnar nerve, or parts in physiological relation with it higher up, the sensation would still be felt in the district supplied by the nerve. You all are aware that persons who have lost limbs by amputation feel the absent member a good while; and they do so by virtue of this law. This law of reference of sensations holds good throughout the sensory tract (æsthesodic tract), from the special senses down.

In the second place, as regards the transmission of motor impulses from the nervous centres outward. Experiments and pathological observations have taught us that in the apparatus for motor manifestations (kinesodic tract) there is also a crossing over of paths. The motor fibres, or, better, paths which transmit impulses to the right leg traverse the median line, though in a very different way from the sensory paths of the same limb. The right half of the spinal cord contains, throughout its length, the motor paths for the right limbs and right side of trunk; no decussation takes place until the lower edge of the medulla oblongata is reached, when all the motor paths cross the median line and enter the left side of the medulla to extend upward to the cerebrum. In the medulla and the pons Varolii the motor paths cross the median line rather higher up than the origin of the motor nerves. The importance of using the word paths instead of nerves, in the present state of our knowledge, is shown in this connection, since physiology and pathology teach that there is a crossing over, while anatomy seems to

demonstrate that all motor nerves (anterior spinal roots) have their nucleus of origin in the corresponding half of the spinal cord; the right sciatic nerve springing from the right anterior horn of the cord, the right hypoglossal and facial nerves from nuclei in the floor of the fourth ventricle on the right side of the median line.

In the third place, the all-pervading function of reflex action—sensori-motor, excito-motor phenomena. The following definition of a reflex action is perhaps sufficient in a theoretical sense: it consists in the transformation, by nerve cells, of a sensitive impression (with or without consciousness) into motion, chemical action, or ideas. The parts essential to the performance of a reflex action consists of a centripetal (sensory) nerve to transmit the excitation, a ganglion cell to transform it into nervous force, and a centrifugal nerve to carry the nervous impulse to the muscle, gland, or cerebral convolutions. The results of the activity of such an apparatus are motion (common muscular, or vascular), secretion, ideation. From this definition you can readily imagine that reflex actions occur in nearly every part of the body, in small segments of it as well as in large portions. A heart cut out of the animal's body will continue to beat some time in response to irritations. Contractions may be obtained by irritating a small portion of intestine removed from the body, and a small segment of the spinal cord will suffice to give reflex movements in the muscles supplied by that piece of cord. Reflex actions take place in all parts of the nervous system (spinal axis, cerebrum, sympathetic system), and at all times; and it is through this kind of action that the most important bodily functions (including in part, certainly, cerebration) are produced. There is a tendency to make all active nervous phenomena of reflex nature, denying the existence of spontaneity in the animal frame, and I must admit that a good deal can be said in support of this extreme view. It would be quite out of place for me to enter into any details about individual reflex actions. I only ask you to remember that many mental manifestations are reflex in character; that respiration, circulation, nutrition, many acts of our life of relation (walking, etc.), are under the control of the law of reflex action; and that many diseases are produced by just the same mechanism.

Lastly, concerning co-ordination of movements. It has been thought, and that within twenty-five years, that there existed a "faculty" of co-ordination (what "faculties" have not been invented by fertile brains!) by the exercise of which our movements are regulated and made perfect. Such a view I need hardly tell you is quite opposed to present physiological and psychological notions. Simple experiments performed long ago show the absurdity of this creation of the theorizer. If the cerebellum or cerebrum be removed from an animal, it is noticed that in the animal deprived of cerebrum there is no impairment of co-ordination at any time: in the case of injury to the cerebellum inco-ordination occurs, and lasts for quite a while; but as shown by Dalton, Lussana, and Weir Mitchell, this disorder ultimately ceases. I have already referred to the experiment of putting nitric acid upon a frog's anus after decapitation, with the effect of causing perfectly co-ördinate movements resulting in the removal of the acid; which movements are so perfect as to have led one German physician at least to admit a consciousness and volition of the spinal cord. These experiments show that co-ordination is a function of many parts of the nervous centres. Another way of studying this function is by watching the physical education of an infant. At first his motions are utterly purposeless and inco-ordinate, but by degrees he acquires the power of moving groups of muscles in a definite way, and at length comes to prehend, to stand, to walk, to speak; and when older he may learn to eat, to play on the piano, to do astonishing feats of hand-skill. By analyzing this progress we reach the conclusion that parts of the nervous centres are educated by repetitions of sensory impressions and of volitional motor impulses, leaving their impress upon groups of cells (so-called centres) which have the property I propose to call retentivity: the cells acquire the "habit" of acting in an automatic, necessary way. It is, furthermore, important to notice in this connection the fact that it is impossible for us to move one muscle alone by a volitional impulse; in other words, the simplest act is co-ordinate. For example, the external rectus muscle of the right eye cannot be made to contract without consentaneous contraction of the internal rectus of the opposite eye; in willed flexion

of the hand the extensor muscles contract as well as the flexors. The best theory of co-ordination, to my mind, is that which, denying all direct (continuous) connection between the cerebrum and individual muscles, admits the existence of educable or educated groups of motor cells in all parts of the spinal axis, which groups act as wholes upon the reception of a volitional impulse. We will to grasp a pen, and, after having learned, we do it without giving any attention to the details of the movements. The necessity of watching movements which should be performed in an automatic way is a serious symptom of disease.

To resume, there are four generalized functions in the nervous system.

1st. Sensation and perception are executed by means of paths which decussate almost horizontally in the spinal axis; the conduction being by the gray matter, not by the white columns of the cord; coarse sensibility with doubtful consciousness has its seat in the pons Varolii; perfect perception and appreciation is possible only with the help of the cerebral mass.

2d. Motion is executed through motor impulses, which, starting from the opto-striate bodies (from cortex of cerebrum also ?) traverse paths which decussate almost opposite the motor nerves as far down as the lower margin of the medulla oblongata, where the paths for the trunk and limbs decussate in a bundle, to remain, below this point, in that half of the spinal cord whence arise the nerves going to the muscles.

3d. Reflex action is the result of a transformation of an irritation from the periphery into nervous force by a nerve cell, transmitted centrifugally by a second nerve. That all nervous phenomena are of reflex mechanism is not to be too positively denied.

4th. Co-ordination is no faculty, but a function of every portion of the motor tract of the spinal axis from the origin of the third cerebral nerve down.

There is not time for, nor had I had the intention of, entering into an analysis of the restricted functions of the organs composing the nervous centres. Even Hitzig's and Ferrier's most interesting researches into the possible motor functions of the cerebral convolutions I must pass by, intending to speak of them in the course of remarks upon the cases which we shall study together this winter.

There are a few pathological laws logically allied to the physiological propositions enumerated above, which I want to submit to you.

1st. Any disease of any part of the nervous centres may produce two kinds of symptoms, which we should always attempt to distinguish: these being symptoms of irritation, consisting, according to the location of the lesion, in exaltation of ideas, delirium, in numbness, pain, and in spasmodic movements; and symptoms of destruction of parts, loss of mental power, anæsthesia, paralysis. Brown-Séquard was, I believe, the first to insist upon the exceeding importance of distinguishing these two classes of effects.

2d. It should be borne in mind that irritating lesions may cause the second class of symptoms by producing an inhibitory (arresting) effect upon centres near or distant.

3d. Ischæmia of the nervous centres produces extreme irritation symptoms, delirium, spasms, pain, and numbness, followed by loss of function of parts.

4th. The effects of hyperæmia are not satisfactorily known.

5th. A want of equilibrium in the circulation of both hemispheres is a common cause of vertigo.

6th. Almost any lesion of the nervous centres may disturb the nutrition of distant (non-nervous) tissues.

7th. A generalized lesion of the convolutions of the brain produces, first, exaltation of mind and emotions, followed by abolition of the faculties, and a false general paralysis.

8th. A lesion of one cerebral hemisphere gives rise to symptoms (paralysis, numbness) in the opposite side of the body and face. The localization of the lesion in the left hemisphere about the fissure of Sylvius, is exceedingly likely to abolish language spoken and written; while lesions of the right hemisphere produce more severe palsy, set the emotions free, and endanger life more.

9th. A lesion of the centre of the pons Varolii will produce general paralysis, with probably anæsthesia and changes in the bottom of the eyes.

10th. A lesion in one-half of the pons Varolii will produce palsy with (probably) anæsthesia in the opposite side of the body.

11th. Lesions of the cerebellum when in one lobe produce an incomplete hemiplegia on the opposite side, with marked eye and stomach symptoms.

12th. A suddenly produced lesion of the centre of the medulla oblongata will probably kill the patient at once by arresting the respiration.

13th. A lesion localized in one-half of the medulla oblongata will give rise to hemiplegia and anæsthesia on the opposite side.

14th. A lesion at the base of the brain, not on the median line, will produce a crossed palsy (as first indicated by Romberg); palsy of body on side opposite lesion, and palsy of one or more cranial nerves on the same side as the disease.

15th. Pressure anywhere within the skull may affect the nutrition of the optic nerves.

16th. In lesions of the cerebral hemispheres accompanied by coma (apoplexy), the eyes are together turned and fixed toward the side of the lesion, and away from the palsied side.

17th. A lesion occupying the whole thickness of the spinal cord, or its gray matter, will give rise to palsy of all parts below the lesion, *i.e.*, below the distribution of nerves issuing from just above the lesion; and such a paraplegia is necessarily attended by anæsthesia, and increased reflex movements in palsied parts.

18th. A lesion in one-half of the spinal cord (hemisection, Brown-Séquard), at any point will produce paralysis with hyperæsthesia on the same side as the lesion, and anæsthesia on the opposite side.

19th. A lesion involving the posterior columns of the spinal cord produces neuralgia and ataxia of movements.

20th. A lesion affecting the lateral columns of the spinal cord will cause a paralysis accompanied by contracture.

21st. A lesion of the cells of the anterior horns of the cord alone will produce a palsy (no anæsthesia), accompanied by extreme wasting of muscles, and loss of electro-muscular reaction. Any part of the spinal axis may be the seat of this disease.

22d. A lesion (destructive) of nerve trunks gives rise to a paralysis with anæsthesia, and rapid loss of electro-muscular reaction.

23d. A lesion in the cerebrum and the opto-striate

bodies may produce secondary lesions in the spinal cord and nerves.

24th. A lesion of the spinal cord may cause secondary lesions upward and downward in the cord, and in nerves.

25th. Lesions of nerve trunks may produce secondary lesions of the spinal cord.